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ABSTRACT

This paper discusses four areas in the psychology literature that have important implications for the instructional design of microcomputer-based simulations. The first one examined is cognitive structures, and the following suggestions for instructional design are offered: simulations should be appropriate for students' level of understanding; simulations should correspond to the actual systems portrayed; the simulation should contain the essential components of the entity it is simulating; the level of detail should be appropriate for the learner; and simulations should be logical and meaningful to students. Suggestions in the area of cognitive and metacognitive strategies are that the simulation should encourage strategies other than drill and practice, support knowledge construction activities, promote concern for cognitive goals, and encourage examination and employment of existing knowledge. In the third area, automaticity of cognitive processes, the following are suggested: make consistent features of the simulated task overt, make the student an active participant, ensure success, strive for stress-free conditions, and isolate automatic components. The final area is affect or motivational appeal, and clear goals, uncertain outcomes, a non-zero based scoring system, competitive situations, and stimulation of curiosity are suggested. (21 references) (MES)

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**Title:**

# Building Microcomputer-Based Instructional Simulations: Psychological Implications and Practical Guidelines

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Abstract

Most theories of instruction specify that students should engage in meaningful interaction within an actual learning situation in order to construct their own understanding of a domain of information. When students do so, the information they glean will be salient, generalizable and less subject to forgetting. Learning from actual situations, however, is often not practical and/or is sometimes expensive (in terms of costs versus benefits) for many learning tasks. Therefore efficient learning sometimes requires the availability and use of instructional simulations and/or other interactive learning environments. Such instructional simulations are now possible and readily available, thanks to the advent of the microcomputer.

In this presentation we target four major topics from psychology that are relevant to the design of microcomputer-based instructional simulations. These four issues are: (a) cognitive structure; (b) cognitive strategies & metacognition; (c) automaticity; and (d) affect. In addition we put forth several guidelines for creating instructional simulations with these topics in mind.

# Building Microcomputer-Based Instructional Simulations: Psychological Implications and Practical Guidelines

## Introduction

The advent of the microcomputer has resulted in an increased interest in the design and use of instructional simulations. This type of simulation has the potential to enhance the transfer of learning by teaching complex mental and procedural tasks in an environment that approximates fairly realistic settings (Reigeluth and Schwartz, 1989). However, many microcomputer-based instructional simulations produced today are poorly designed from a psychological standpoint (Hill, 1989), and therefore do not provide an effective learning environment.

There seems to be a dearth of information concerning how to specify and implement appropriate instructional designs for this type of learning context (Alessi, 1988). This presentation represents our attempt at identifying areas in the psychological literature which have important implications for the instructional design of microcomputer based simulations. Following is a representative summary of the information we have gleaned from research in the areas of training, instruction, cognitive psychology, and human factors. In our presentation we will present these themes and concepts in a much finer level of detail.

## Cognitive Structure

Our view of the world, of ourselves, of our capabilities, and of the tasks we are asked to perform, depend quite a bit on the mental conceptualizations we bring to a task. As we act and react to the environment, to others, and to the machines (including training devices) around us, we form and/or modify our internal mental representations of the things with which we are interacting. These statements hardly need to be said but we do so because they represent an underlying theme which will surface again and again as we discuss the psychology of instructional simulations.

Implications. One of the key questions a designer of instructional simulations needs to ask is; "What constitutes good strategies for making instructional simulations conducive to improving cognitive structure?" We give several suggestions below.

- Simulations should use **appropriate** imagery, audio, vocabulary and organization for the level of understanding the student is at.
- Simulations should **correspond** (at some level) to the actual systems they portray. The major elements and interactions in a simulation should conform to the major elements and interactions in the actual system.

• Present the **essential** system. The simulation should contain all the essential components, conditions, states and actions of the entity it is simulating.
• Use **appropriate detail**. The simulation should be given a level of detail that is adequate for the learner.
• Make the simulation **logical** to the user. Well designed instruction (simulation based or other) makes intuitive sense to students.
• Simulations should be inherently **meaningful** to students. That is, simulations should be based on material that explains how a system operates.

We see then, that instructional simulations are usually conducive to improving cognitive structure when they are matched with the cognitive level of the student and their instructional goals.

Cognitive and Metacognitive Strategies

Cognitive strategies are students' actions and thoughts that occur during learning and that influence motivation and encoding, including acquisition, retention, and transfer. Metacognitive strategies, on the other hand, refer to students' knowledge about and control over their cognitive processes (Wittrock, 1986). Both these terms are broad and loosely defined areas that relate to many of the issues discussed previously.

Successful students are found to use a variety of cognitively oriented strategies to: (a) pursue learning goals; (b) relate new knowledge to old; (c) monitor understanding; (d) infer unstated information; and (d) review, reorganize, and reconsider their knowledge (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989).

On the other hand (and perhaps more importantly), recent cognitive research also indicates the ways unsophisticated learners approach and think about learning. Recent literature, such as Scardamalia, et al. (1989), indicates that unsophisticated learners are prone to: (a) mentally structure information by topic rather than by goal (Schoenfield & Herman, 1982), (b) focus mainly on surface features (Chi, Feltovich & Glazer, 1981; Silver, 1979), (c) use straight ahead rather than recursive procedures (Anzi & Simon, 1979), and (d) use an additive rather than transformational approach to learning.

Implications. These findings indicate that in order for instructional simulations to support expert-like (meta) cognitive strategies, they will need to encourage students to take an active part in the learning process, rather than the passive role they are often assigned (or often assign themselves). But how can such support be provided ?

Foremost, the simulation needs to provide the kind of support that will enable learners to take maximum advantage of their own intelligence and competence. Following are some suggestions for developing the kinds of supports that are needed in simulation based training.
• Encourage strategies other than "practice." or "rehearsal."
• Support **knowledge construction** activities.

• Make concern for **cognitive goals** a very high priority. Make certain that students are aware of the cognitive goals that are to be achieved by using the simulation.
• Encourage **examination and employment** of existing knowledge.

Automaticity of Cognitive Processes

When a task can be performed such that it no longer requires the deliberate attention of the student, it is said to be automatized. A large body of scientific research points to the fact that automatic cognitive processing is a fast, parallel process, not limited by short-term memory, requiring little effort or attention by the performer, but requiring extensive and consistent practice to develop. Its use is heavily implied in various aspects of skilled behavior such as reading, playing a piano, or flying an aircraft. In contrast, controlled cognitive processing demands much attentional capacity, is serial in nature, is limited by short-term memory, and frequently requires conscious effort (Fisk, 1989).

Implications. Research shows that for many tasks, both behavioral and cognitive, automaticity develops slowly and often only after massively repetitive practice (Myers & Fisk, 1987). The single most critical factor in determining how well a skill is automatized seems to be the manner in which the task is presented to the learner. As Fisk (1989) stated;

> "Research supports the common observation that the way people typically perform a novel task (i.e., in a slow, effortful, and error-prone manner) is quite different from how they perform the task after lengthy practice (i.e., quickly, accurately, and with little effort). Such performance differences between novice and skilled individuals have led researchers to suggest that complex performance is the result of two distinct forms of information processing. In this paper we refer to these processes as automatic and controlled information processing. . . . Automatic processes can be developed only through extensive practice under consistent conditions. . . . Conversely, the use of controlled processes is implied when no consistent rules or no consistent sequences of information processing components are present in a task. (p. 453-454)

Automaticity then seems to be the result of repeated exposure to consistent stimuli over a relatively short period of time. In addition to the admonition that tasks must be consistently presented in order for automaticity to occur, several other implications can be gleaned from recent research.
• Make the **consistencies overt**. Under certain conditions, the consistent features of the simulated task may need to be pointed out to students so that they can "tune-in" to them (Fisk & Schneider, 1981).
• Make the student an **active participant** rather than passive observer. Automaticity implies active responding. The simulation should strive to make the student respond overtly to the situation (Schneider, 1985).

• The difficulty level of the simulated task should be such that students are **consistently successful** at performing it. Students may need massive amounts of "successful" practice before the skill will be automatized.
• Training should take place under **relatively stress free** conditions. A good instructional strategy is to increase the stressfulness of the simulated task only after it is well on its way to being automatized.
• **Isolate components** of tasks which one wishes to automatize. Frederiksen and White (1989) have shown that it is possible to decompose cognitive tasks and isolate their components so that automatization through training can take place.

Affect

The last issue concerns affect or the motivational appeal of the instructional simulation. At first blush, affect may seem to be fairly unimportant. However, a meta-analysis by Deckers and Donatti (1981) indicates that while simulations may not always be more effective than conventional instruction methods, they exhibit a high motivational component. Earlier studies by Taylor and Walford (1972) and Thiagariajan (1973) concur with this finding. According to Adams (1973), it is a simulations power to "unite the cognitive and affective areas" that makes it potentially useful.

Implications. Affect is a very complex construct, and as such, manifests itself in many ways. For example Dittrich's (1977) studies led him to conclude that a simulation's perceived fidelity is more motivational for learning than actual fidelity. He suggested that either very low or very high fidelity simulations will be perceived as low while medium fidelity simulations will be perceived as high and hence will enhance positive motivation on the part of students. Other research shows that when the (poor) attitude of students requires highly motivational instruction, simulations incorporating principles of gaming should be created (Malone, 1981; Priestley, 1984; Reigeluth and Schwartz). Research by Malone (1981) indicates that three factors, challenge, fantasy, and curiosity contribute to creating a positive affect on the part of learners. The specific guidelines that follow provide a brief summary of some of the relevant literature.

• Provide clear **goals** for students to attain.
• Provide **uncertain outcomes**. If learners are absolutely certain to reach the goal or certain not to reach it, the simulation is probably not challenging enough to sustain their interest.
• Use a **non-zero based scoring** system.
• Create **competitive** situations.
• Stimulate, satisfy, and sustain student **curiosity**.

Summary of Issues and Implications

Table 1 summarizes the issues and their implications for the design and

use of instructional simulations. Many of these implications are not mutually exclusive, but typically perform interactively during an instructional simulation. They are set apart here to emphasize the underpinnings of the cognitive approach.

While these issues are probably not new or unfamiliar to training professionals, it is our observation that they are not being considered to the degree that they could be in the design of simulation programs used for training and instruction. We believe that instructional simulations should be designed, used, and evaluated with these implications in mind.

**Table 1.** Some Issues and Implications for Instructional Simulations

| Issues | Implications |
|---|---|
| Cognitive Structure | Make simulations appropriate for the level students are at |
| | Make simulations correspond to actual systems |
| | Present only the essential system |
| | Use appropriate detail |
| | Make the simulation logical to the student |
| | Make simulations inherently meaningful to students |
| Cognitive Strategies and Metacognition | Encourage strategies other than "practice" or "rehearsal" |
| | Support knowledge construction activities |
| | Make concern for cognitive goals a high priority |
| | Promote examination and employment of existing knowledge |
| Automaticity of Cognitive Processes | Make consistencies overt |
| | Encourage active participation rather than passive |
| | Structure difficulty to so as to ensure consistent success |
| | Strive for relatively stress free conditions |
| | Isolate automatic components |
| Affect | Provide clear goals |
| | Provide uncertain outcomes |
| | Use a non-zero based scoring system |
| | Provide a competitive situation |
| | Stimulate, satisfy, and sustain curiosity |

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